



Discovery of a third species of the genus *Noguchiphaea* Asahina, 1976 – *Noguchiphaea laotica* sp. n. from Laos (Odonata: Calopterygidae)

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A new species, *Noguchiphaea laotica*, is described based on specimens from Lon San, Saysomboun Province, Laos. The holotype male and a paratype female are deposited in the National Museum of Nature and Science, Tokyo. This new species is allied to *N. yoshikoe* from northern Thailand, but differs from it in the morphology of the male cercus which is depressed centrally apically in dorsal view, and with a more robust dorsal spine at about one-third from its base. In addition, DNA analyses confirm that there are genetic differences between *N. laotica* and *N. yoshikoe*. Some observations on the ecology and behavior of *N. laotica* are briefly reported.

<http://www.zoobank.org/urn:lsid:zoobank.org:pub:44D39DC5-40A5-4F33-B951-D3AD0B5247B7>

Keywords: Calopteryginae; Caliphaeinae; Noguchiphaeini; *yoshikoe*; Lon San Laos; DNA; dragonfly

Introduction

Noguchiphaea Asahina, 1976 is a small oriental calopterygid genus with only two previously described species. The type species, *Noguchiphaea yoshikoe* Asahina, 1976, was described on the basis of two male specimens from Doi Inthanon, Chiang Mai Province, northern Thailand. Until now, this species has been recorded from several localities in northern and northwestern Thailand (e.g. Day et al., 2012; Hämäläinen, 2017; Makbun, Kulsarin, Buranapanichpan, & Hämäläinen, 2011), northern Vietnam (Do, 2008; Phan, Do, & Hämäläinen, 2011; Kompier, pers. comm.), and Yunnan Province of PR China (Zhang, 2017) (Figure 10; Table 1).

The other species, *Noguchiphaea mattii* Do, 2008, which is peculiar with a longer abdomen, is only known from the type locality, Hon Ba Nature Reserve in Khanh Hoa Province in central Vietnam. The habitats of both species are limited to well-preserved forested montane areas, and they are probably localized, but little is known about their whole distribution.

The characters of this genus were well defined by Asahina (1976, 1981, 1985) as follows: wing with limited petiolation, pterostigma absent in both fore and hind wings, no cross-veins

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Table 1. The hitherto known habitats of three *Noguchiphaea* species. Numbers correspond to those in Figure 10.

Species name	Locality name	Source of records
<i>Noguchiphaea laotica</i>	[LAOS] Lon San, Saysomboun Prov. (type locality) (1); 7 km West from Cha, Saysomboun Prov. (2)	This paper
<i>Noguchiphaea yoshikoeae</i>	[THAILAND] Doi Inthanon, Chiang Mai Prov. (type locality) (3); Pai, Mae Hong Son Prov. (4); Doi Suthep-Pui NP, Chiang Mai Prov. (5); Mae Ton Luang, Chiang Mai Prov. (6); Phu Ruea, Loei Prov. (7); Phu Luang Wildlife Sanctuary, Loei Prov. (8); Phu Hin Rong Kla NP, Phitsanulok Prov. (9); Thung Salaeng Luang NP, Phitsanulok Prov. (10). [VIETNAM] Tam Dao NP, Vinh Phuc Prov. (11); Xuan Son NP, Phu Tho Prov. (12); Pia Oac NR, Cao Bang Prov. (13) [PR CHINA] Tongbiguan National NR, Yunnan Prov.* (not included in Fig. 10)	(3) Asahina (1976); (4, 6) Hämäläinen (pers. comm.); (5) Makbun et al. (2011); (7) Day et al. (2012); (8) Makbun & Makerd (pers. comm.); (9) Makbun & Atthakant (pers. comm.); (10) Makbun & Day (pers. comm.); (11) Do (2008); (12) Phan et al. (2011); (13) Kompier (pers. comm.); * Zhang (2017)
<i>Noguchiphaea mattii</i>	[VIETNAM] Hon Ba NR, Khanh Hoa Prov. (type locality) (14)	Do (2008)

Abbreviations: NP, national park; NR, nature reserve.

in quadrangle, basal R_{2+3} vein shortly fusing with R_1 , and only one cell row between A_1 and wing margin; male with characteristic anal appendages and simple genital ligula; female with pair of long protuberances on the posterior lobe of prothorax, and with laterally serrated edge to ovipositor. Asahina (1976) considered that some of these features are held in common with the genus *Caliphaea*, therefore he placed *Noguchiphaea* under the subfamily Caliphaeinae.

Recent molecular studies have revealed the uniqueness of this genus, but, at the same time, implied the complexity of its status in the family Calopterygidae. Dumont, Vanfleteren, De Jonckheere, and Weekers (2005) indicated that *Noguchiphaea* is grouped with the genus *Iridictyon* distributed in South America, but that the former is not in the same clade with *Caliphaea*, based on analyses of ribosomal RNA (18S, 5.8S) and DNA of internal spacer (ITS1 and ITS2). Conversely, Dumont, Vierstraete, and Vanfleteren (2010) reported that *Noguchiphaea* is coupled with *Burmargiolestes* (which belongs to an “incertae sedis” group by Dijkstra, Kalkman, Dow, Stokvis, & van Tol, 2014) in a clade, and they are paraphyletic with other Calopterygidae clades (including *Caliphaea*), based on analysis of ribosomal gene 18S. Unfortunately, Guan, Han, Vierstraete, and Dumont (2012) did not include *Noguchiphaea* in their tree and discuss its affinities, although *Iridictyon* was included. Dijkstra et al. (2014) placed *Noguchiphaea* in the tribe Noguchiphaeini in the subfamily Calopteryginae. Anyway, although the exact phylogenetic status has not yet been resolved, the genus *Noguchiphaea* should be considered as rather unique within the family.

Recently we discovered a third species of the genus *Noguchiphaea* from Laos. Superficially it resembles closely *N. yoshikoeae*, but detailed examinations revealed clear morphological differences. Also molecular studies support its status as a distinct new species, which is here described and named as *Noguchiphaea laotica* sp. n.

Material and methods

The data of specimens examined are as follows:

Noguchiphaea laotica specimens are detailed in the description of the species below.

Noguchiphaea yoshikoe (Thailand): 2♂ (holotype & paratype), Doi Inthanon (1200 m), 17 September 1975, R. Kano & H. Kurahashi leg.; 1♂, Mae Khun Khlang, 17 October 1983, S. Ae leg.; 1♀ (allotype), Doi Suthep, 1 August 1976, S. Tsuda leg.; 1♀, the same locality, 27 July 1980, K. Kitagawa leg. above all in National Museum of Nature and Science, Tokyo; 1♂, Doi Suthep, 8 November 2004, M. Hämäläinen leg. in Kanagawa Prefectural Museum of Natural History.

? *Noguchiphaea yoshikoe* (N. Vietnam): 1♀, Xuan Son National Park, Phu Tho Province, 23 November 2014, Phan, Q. T. leg; 2♂, same locality and collector, 14–15 September 2015.

The external morphology of specimens was studied using a binocular stereomicroscope (Olympus SZ40, Nagano Prefecture, Japan). Photos of small structures like the anal appendages, genital ligula, and female ovipositor were obtained using a Canon EOS 40D (Tokyo, Japan) through the stereomicroscope employing an AmScope (Zhejiang, China) attachment. The photos were combined automatically into a single stacked image using the software CombineZM® (Hadley, 2014). Schematic line drawings (Figure 4) were made by transcribing images on the ocular grid micrometer of the stereoscope onto grid paper by hand.

Measurements were made by Vernier caliper in tenths of millimeters.

Nuclear and mitochondrial DNA analyses of several *Noguchiphaea* specimens and allied species were previously analyzed and deposited in the DDBJ/EMBL/GenBank databases (Futahashi, 2011, 2014), and these sequences were aligned using Clustal_X (Thompson, Gibson, Plewniak, Jeanmougin, & Higgins, 1997). Molecular phylogenetic analyses were conducted by three methods, neighbor-joining with MEGA6 (Tamura, Stecher, Peterson, Filipski, & Kumar, 2013), maximum likelihood with MEGA6 (Tamura et al., 2013), and Bayesian with MrBayes v3.2 (Ronquist et al., 2012). The maximum composite likelihood and Tamura Nei models were used for neighbor-joining and maximum likelihood analysis, respectively (Tamura & Nei, 1993). Bootstrap values for neighbor-joining and maximum likelihood phylogenies were obtained by 1000 bootstrap replications. For Bayesian analysis, Markov chain Monte Carlo (MCMC) analysis was performed under the general time reversible + invariable sites (GTR + I) model. In total 3750 trees were generated for each Bayesian analysis (ngen = 500,000, samplefreq = 100, burn in = 1250).

Abbreviations: A₁, 1st anal vein; c, costal space; Fw, forewing; Hw, hind wing; R₃, 3rd radius vein; S, segment; sc, subcostal space.

Taxonomy

Noguchiphaea laotica Sasamoto, Yokoi & Souphanthong sp. n.

(Figures 1, 2, 3a, 4, 5a, b, 6–10)

Noguchiphaea sp. 1 & sp. 2: Yokoi & Souphanthong, 2014, pp. 10, 28 (male photos), 62 (data), 72 (map).

Etymology

The species name is a Latin adjective referring to the country Laos in which the type locality is situated (officially: the Lao People's Democratic Republic).

Type specimens

Holotype ♂, Lon San, Saysomboun Province, Laos (18.51416° N 103.00555° E), 12 October 2010, N. Yokoi leg. – Paratypes: 1 ♂, 1 ♀, same locality and collector as holotype, 25 October 2008; 10 ♂, 6 ♀, same locality and collector as holotype, 12 October 2010.



Figure 1. Habitus of holotype ♂ of *Noguchiphaea laotica* (Lon San, Saysomboun Prov., 12 October 2010) (scale bar: 1 cm).

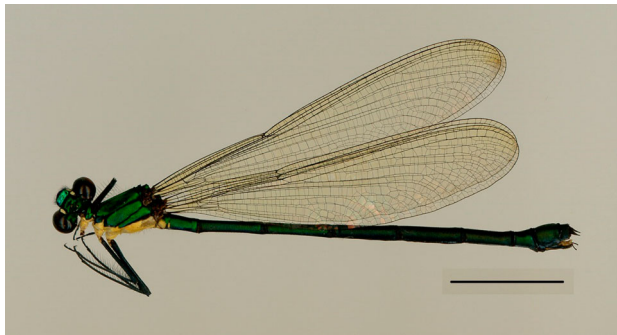


Figure 2. Habitus of a paratype ♀ of *Noguchiphaea laotica* (Lon San, Saysomboun Prov., 12 October 2010) (scale bar: 1 cm).



Figure 3. Ventral part of head of *Noguchiphaea laotica*, holotype ♂ (a) and *N. yoshikoe* ♂ (b) (Doi Suthep, N. Thailand, 8 November 2004, M. Hämäläinen leg.).

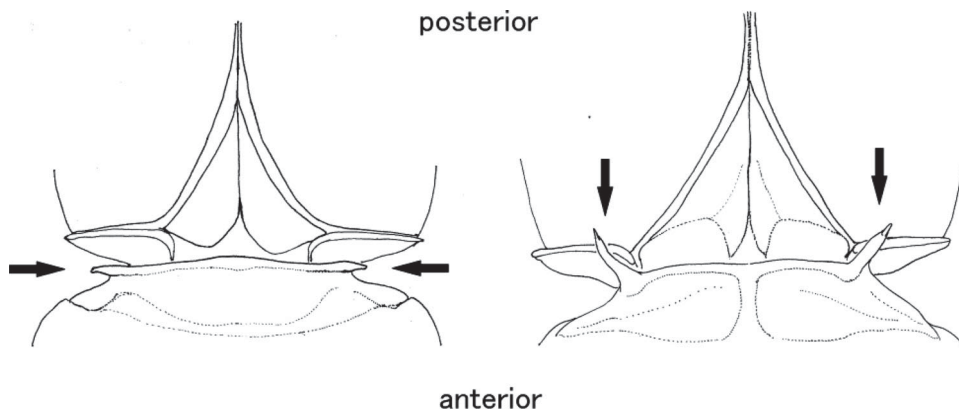


Figure 4. Process (arrowed) on the posterior lobe of prothorax and mesostigmal plate in dorsal view of *Noguchiphaea laotica*. (a) Holotype ♂; (b) paratype ♀.

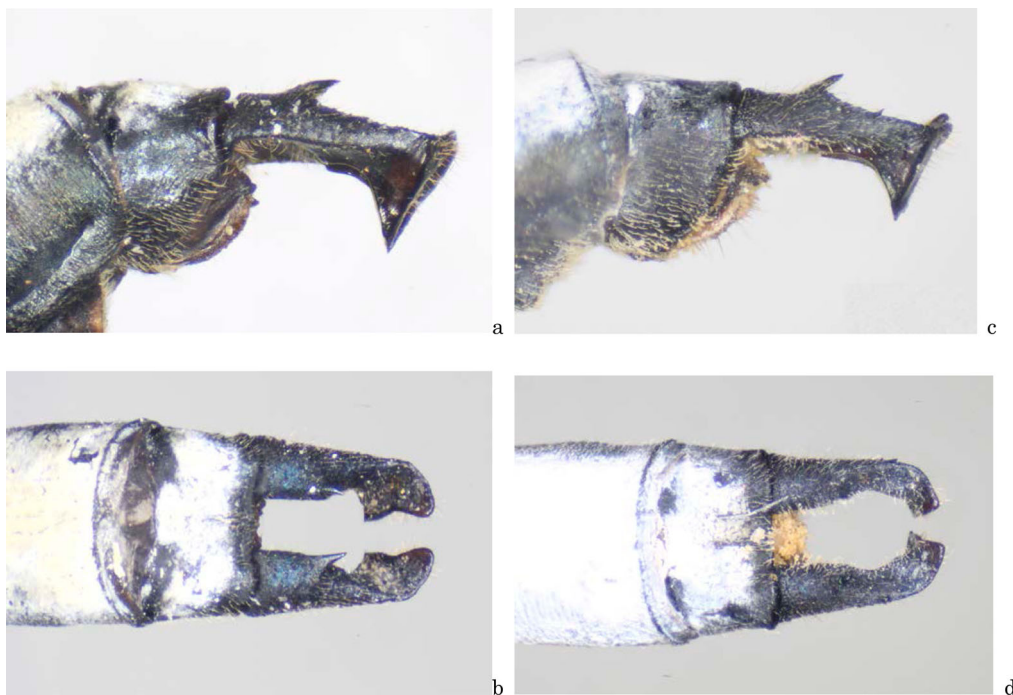


Figure 5. Anal appendages of *Noguchiphaea laotica*, holotype ♂ (a, b) and *N. yoshikoae* ♂ (the same specimen as Figure 3b) (c, d). (a, c) Lateral view; (b, d) dorsal view.

Additional materials examined. 2 ♂, 7 km West from Cha, Saysomboun Province, Laos (18.88555° N 103.04083° E), 9 October 2008, N. Yokoi leg.; 2 ♂, 1 ♀, same locality and same collector, 23 September 2011.

The holotype (NSMT-I-Od-32336) (Figure 1) and one female paratype (Lon San, Saysomboun Prov., 12 October 2010) (NSMT-I-Od-32337) (Figure 2) are deposited in the National Museum of Nature and Science, Tokyo. The other paratype specimens are preserved in the private collections of Akihiko Sasamoto, Naoto Yokoi and Matti Hämäläinen.

Description of holotype male

A slender and medium-sized, hyaline winged calopterygid with long abdomen, colored with metallic green and yellow (Figure 1).

Head. Labium smoky yellow basally, with black in distal third of lateral lobes and distal half of median lobe, including movable hooks (Figure 3a); labrum, ante- and postclypeus, frons, vertex and occiput luster metallic green; genae metallic black; mandibles creamy yellow, margined with thin black; antennae black with conspicuous creamy white on the anterior surface of scape; rear of the head black.

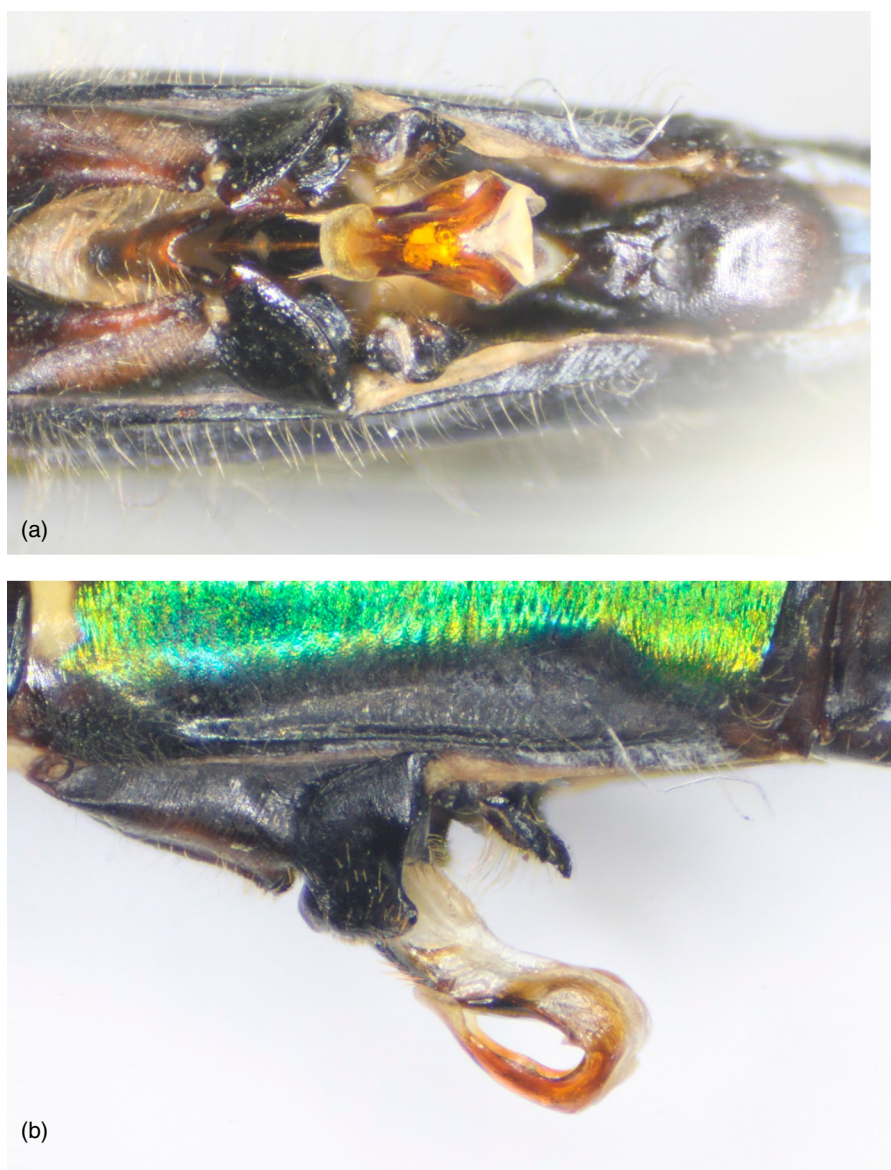


Figure 6. Genital ligula of *Noguchiphaea laotica*, holotype ♂. (a) Ventral view; (b) lateral view.



Figure 7. Distal abdomen of a paratype ♀ (Lon San, Saysomboun Province, Laos, 12 October 2010, N. Yokoi leg.).

Thorax. Prothorax luster green with lower margin yellow; side of hind margin of posterior lobe with a pair of small processes, turning laterad (Figure 4a). Synthorax luster metallic green with blackish margin, and creamy yellow parts; mesepisternum wholly metallic green, mesepimeron and metepisternum metallic green with creamy yellow on ventral corner; black on humeral and first lateral suture; metepimeron creamy yellow with an ambiguous dirty black spot near the center, with black margins on dorsal side and near upper part of 2nd lateral suture; mesoinfraepisternum metallic green on upper half and yellow on lower half; metainfraepisternum and ventral part of synthorax creamy yellow. Legs black, with coxae and trochanters yellow.

Wings. Hyaline, very thinly smoked yellowish brown; a small black spot on tip of Fw, the same on Hw very faint; antenodal veins 17 and 16 in costal space (*c*) and 16 in subcostal space (*sc*) in Fw, 14 and 15 in *c* and *sc* in Hw; postnodal ones 34 and 37 in Fw, 31 and 32 in Hw; pterostigma absent in both wings; R_3 arising about 3 cells distal from subnodus in Fw, while 2.5 cells in Hw; A_1 in Hw running almost parallel with posterior margin, extending 5 or 6 cells beyond the nodal position, a cell row between A_1 and posterior margin; basal and quadrangle cells entire in both wings; cubital spaces with 2 or 3 crossveins in Fw and Hw; petiolation of both wings, very weak, around level of 1st antenodal vein.

Abdomen. S1 yellow, fringed black posteriorly, with metallic green dorsally; S2 to S10 metallic green, gradually dull color posteriad, with ventral part blackish; S2 with a small yellow spot near anterolateral border; dorsa of S8 to S10 pruinose with greyish white.

Genital ligula (Figures 6a, b) Third (apical) segment is spoon-like shaped, gently curled in edge, with a shallow notch in center apically; second segment with pairs of robust short setae in a row.

Anal appendages (Figures 5a, b) Black; cercus in lateral view broad, divergent apically, extending obliquely downwards, the ventral side arched gently curving; cercus with a robust

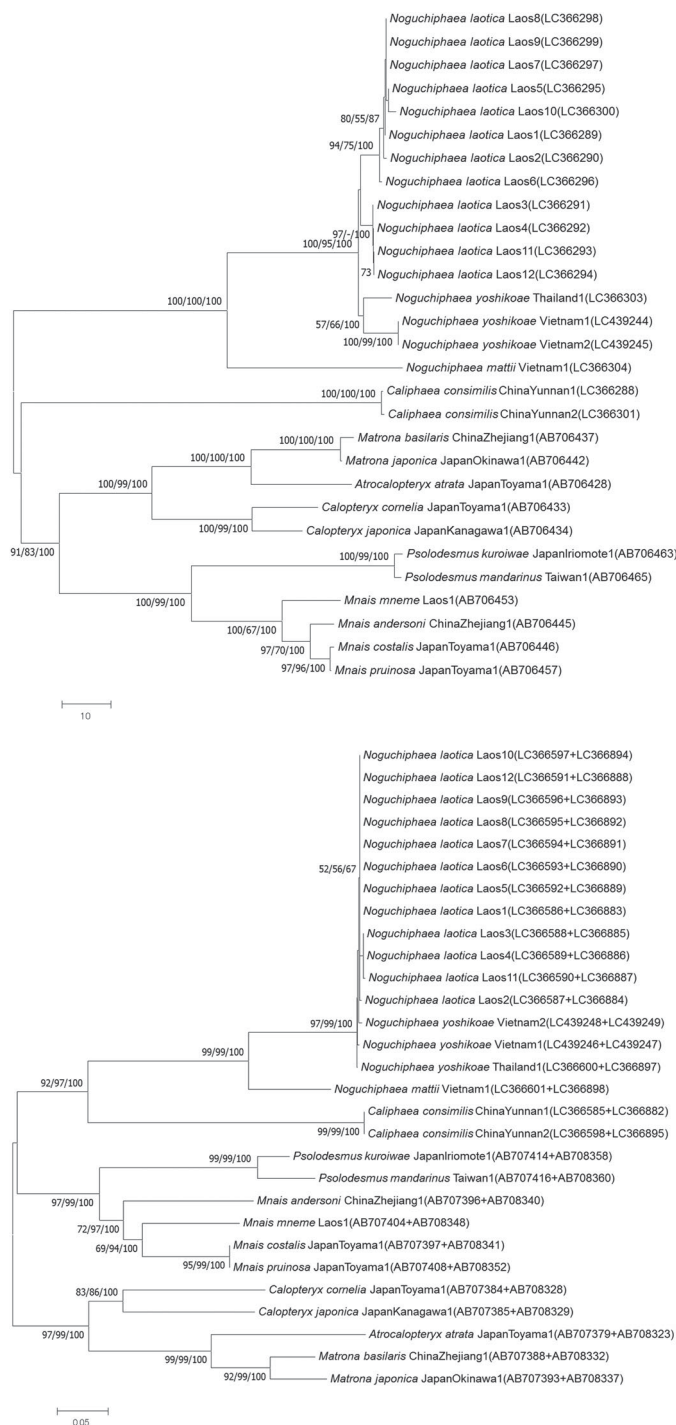


Figure 8. Molecular phylogenetic analysis of *Noguchiphaea* and its allies. A neighbor-joining phylogeny is shown; maximum likelihood and Bayesian phylogenies exhibited substantially similar topologies. On each node, statistical support values are indicated in the order of [bootstrap value of neighbor-joining]/[bootstrap value of maximum likelihood]/posterior probability (percentages) of Bayesian]. Hyphens indicate support values lower than 50%. The number in parentheses after each species name is accession number in the DDBJ/EMBL/GenBank databases. (a) Nuclear DNA genes (ITS1 + 5.8S + ITS2, 661 bp), (b) mitochondrial DNA genes (16S rRNA + COI, 966 bp).



Figure 9. Photos of *Noguchiphaea laotica* in nature. (a) ♂; (b) ♀, (c) oviposition, (d) habitat.

dorsal spine at about one-third from its base, which is directed obliquely dorsoposteriad; apical side of cercus almost linear in lateral view, whereas in dorsal view gently depressed in the center, the ventral corner of which slightly acute, whereas the dorsal corner rounded; paraproct rudimental, short and simple, triangular in lateral view.

Measurements (in mm) Hw 31.1; abdomen (incl. appendages) 44.0.

Description of paratype females

General appearance and markings (Figure 2) similar to those of male, but proportion of length of abdomen to Hw smaller than that of male. Hind margin of posterior lobe of prothorax with a pair of erect processes horn-like (Figure 4b). Tip of wing tinted a little brownish, but less dark than male. Nodal index: antenodal veins 17 to 20 in Fw, 14 to 18 in Hw; postnodal veins 33 to 37 in Fw, 31 to 34 in Hw. Abdomen broadly yellow on lateral side of S1, a small yellow spot near lateroapical border of S2 and S3. Ovipositor dark green with pale yellow on dorsal part and ventral base; tip of ovipositor reaches to, or slightly beyond, posterior margin of S10; lateral valvula with 14 to 18 serrated spines, which are gradually bigger posteriad (Figure 7). Cerci black, slender triangularly shaped in dorsal and lateral views.

Measurements (in mm) Hw 32.6–33.5; abdomen (incl. appendages) 38.0–38.3.

Variation in paratype males

There is only a little variation in body markings. Two specimens have a very tiny rudimental spine on dorsum at apical third of cerci. Variation of nodal index: antenodal veins 15 to 18 in



Figure 10. Distributional map of *Noguchiphaea*. White circle: *N. laotica*; black circle: *N. yoshikoe* (Yunnan record not mapped); white square: *N. mattii*. The exclamation marks indicate the type localities. See Table 1 for more on each number.

Fw, 14 to 16 in Hw; postnodal veins 32 to 35 in Fw, 29 to 33 in Hw. The brownish tip to wings is absent in immature specimens. Measurement ranges are Hw 31.2–32.4 mm, abdomen (incl. appendages) 44.5–45.9 mm.

Geographical variations

All of the males from “7 km west from Cha” have a tiny dorsal spine at one third length of cercus from its apex, which is also present in two paratype males from Lon San.

Diagnosis

This new species, *Noguchiphaea laotica*, more closely resembles *N. yoshikoe* than *N. mattii*. *N. mattii* has a longer abdomen and very characteristic morphology of anal appendages, i.e. the

superior of which does not expand apically and inferior of which is relatively much longer (Do, 2008). Compared with Thai *N. yoshikoeae*, *N. laotica* differs by apical margin of male cercus, which is centrally depressed in dorsal view (Figure 5b), whereas that of *N. yoshikoeae* is almost straight (Figure 5d; Asahina, 1976), and by a dorsal spine at about basal one-third of cercus that is more robust (Figure 5a) than in *N. yoshikoeae* (Figure 5c).

In addition, in the material we examined, *N. laotica* in both sexes has a smoky yellow labium at base (Figure 3a), whereas the labium in Thai *N. yoshikoeae* has mostly a darkish color (Figure 3b). However, such color characteristics may be variable individually or at aging stage.

It should be noted that N Vietnamese *N. yoshikoeae* has, although previously identified as this species (e.g. Do, 2008), somewhat different morphology from Thai individuals. For example, cercus of Vietnamese *N. yoshikoeae* has a row of small processes inwards near apex, although the apical side is similar with that of the Thai population. Due to only very limited materials available, we refrain from discussing the Vietnamese and Chinese populations here.

This group has relatively poor maculation and simple genital structure, therefore characteristics of each species are not distinct. In summary, the most reliable difference between *N. laotica* and Thai *N. yoshikoeae* is the morphology of apical side of the cercus, i.e. centrally depressed in the former, nearly straight in the latter.

Molecular phylogenetic analysis

The results are shown as phylogenetic trees in Figure 8a and 8b, respectively.

In the analysis of nuclear DNA (Figure 8a), *N. laotica* is near to, but separated from, Thai *N. yoshikoeae*. Moreover, there are certain differences between the populations from Lon San and “7 km west from Cha”, which may imply that genetic segregation is occurring between these two populations of *N. laotica*.

Conversely, in the mitochondrial DNA analysis (Figure 8b), there are no significant differences between *N. yoshikoeae* and *N. laotica*. Several cases have been reported showing no significant differences detected between different allied species due to mitochondrial introgression (e.g. Futahashi, 2011).

Notes on behavioral ecology

The second author (Yokoi) observed *N. laotica* in the field. This species seems to appear only in autumn. We could not find any in spring to early summer in the same place. The habitat of Lon San is around a small stream in a well-preserved mountain forest (Figure 9d), where *Coelliccia* and *Planaeschna* species were seen at the same time in autumn. The adults of *N. laotica* settled on leaves in the shade of trees, and rarely appeared in bright places near the water surface. Five ovipositions were observed; all females laid eggs into the hard bark of living plants, one to two meters above the water surface of streams (Figure 9c). Their seasonal appearance, their habitat, and their behavior, including oviposition, are likely in common with those of *N. yoshikoeae* in Thailand, Vietnam and S. China (Hämäläinen, 2017; Karjalainen & Hämäläinen, 2013; Makbun et al., 2011; Phan et al., 2011; Zhang, 2017; Kompier pers. comm.).

Discussion

The specimens from “7 km west from Cha” of the same province show subtle morphological differences in the male anal appendages and certain genetic divergence, but due to the small number of examined specimens, we provisionally put them among *N. laotica*. In addition, our

DNA analyses suggest the possibility that the population from northern Vietnam “*Noguchiphaea yoshikoe*” is genetically differentiated from the Thai population (Figure 8). The appropriate taxonomic positions of these populations are expected to be determined in the future.

In the past, only small numbers of specimens were obtained from a few scattered localities; however, in recent studies, it has been gradually revealed that *Noguchiphaea yoshikoe* has a broader range and that it is not as rare as previously believed. In contrast, only a few specimens of *N. mattii* have been recorded from its type locality, Hon Ba, C. Vietnam. All three species are localized and elusive inhabitants of well-preserved natural forests from Indochina to S China.

As mentioned in the Introduction, the exact phylogenetic status of *Noguchiphaea* among the Calopterygoidea has not been elucidated. As well as molecular analysis of higher taxa, the peculiar behavioral ecology, e.g. oviposition style and late season occurrence, implies that this group appears to occupy a special position in the family Calopterygidae.

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